Status of US NRC Research Activities for Alloys 690/52/152

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EPRI Alloy 690/52/152 PWSCC Research Collaboration Meeting

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Outline

- Objectives of NRC sponsored PWSCC testing
- Summary of testing conducted
  - Alloy 690
  - Alloy 152
  - Alloy 52
  - Weld dilution zones
- Progress towards addressing information gaps
- Priorities for future work

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Objectives of NRC Sponsored PWSCC Testing

- Crack growth rate data to inform inspection requirements
  - Components manufactured using alloy 690/152/52
  - Weld overlays and inlays
  - Environment modifications such as hydrogen additions and zinc additions
- Confirmatory crack growth rate testing of alloy 600/182/82 when degradation has been observed in service

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PWSCC testing conducted (1/2)

- Alloy 690 As-Received
  - 5 heats tested
  - 3 heats of Valinox CRDM tubing 690TT
  - 2 heats of mill annealed 690 plate
- Alloy 690 Cold Worked
  - 12 heats tested (11/2012) and 5 additional heats currently in test
  - 50+ tests (GE, PNNL, ANL and AMEK)
  - Crack growth rate vs. misorientation/hardness (S.M. Bruemmer presentation)
- Alloy 690 Heat Affected Zone (HAZ)
  - HAZ tests conducted with 6 heats of Alloy 690
  - SMAW HAZ in mill annealed (MA) heat NX3297HK12 tested by ANL and PNNL
  - Lazer weld in MA heat NX3297HK12 tested by GE

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PWSCC testing conducted (2/2)

- Alloy 152
  - 9 heats tested
  - 7 tests using 7 heats tested by GE
  - 11 tests using 4 heats tested by ANL and PNNL
- Alloy 52
  - 9 heats tested including 52, 52i, 52M and 52MSS
- Alloy 52 Overlay/Inlay
  - 7 tests using 2 Alloy 52M heats conducted by ANL and PNNL
- Weld Dilution Zone
  - 4 tests using 152M-LAS, 52M-LAS, and 152-SS at PNNL
  - 2 tests using 52M-182 (overlay) at ANL
  - 2 tests using 152-LAS at ANL (B. Alexandreanu presentation)

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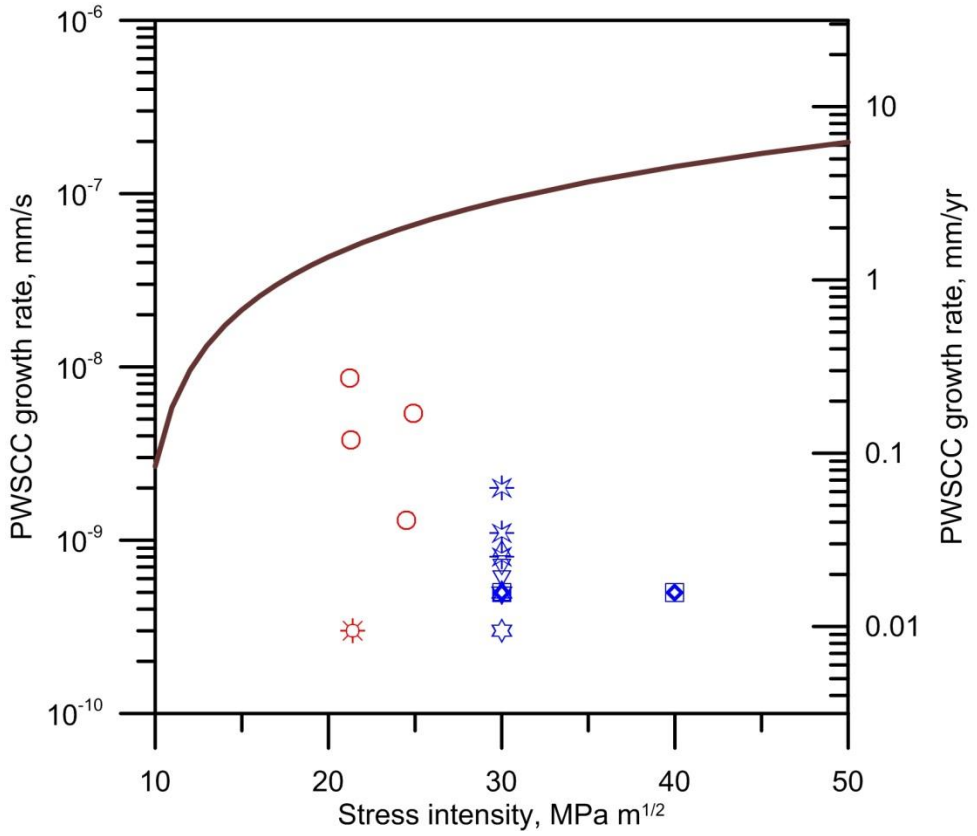
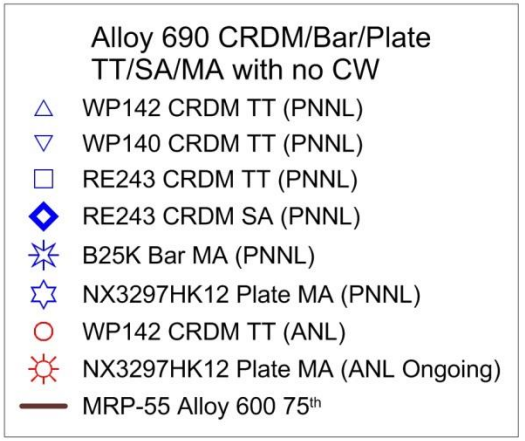
Alloy 690





- Limited number of tests with as-received Alloy 690
- 5 additional heats under test with 11.6 to 22 percent cold work

- Mill Annealed (MA) and Thermally Treated (TT) Alloy 690 materials show similar crack growth rates with no cold work

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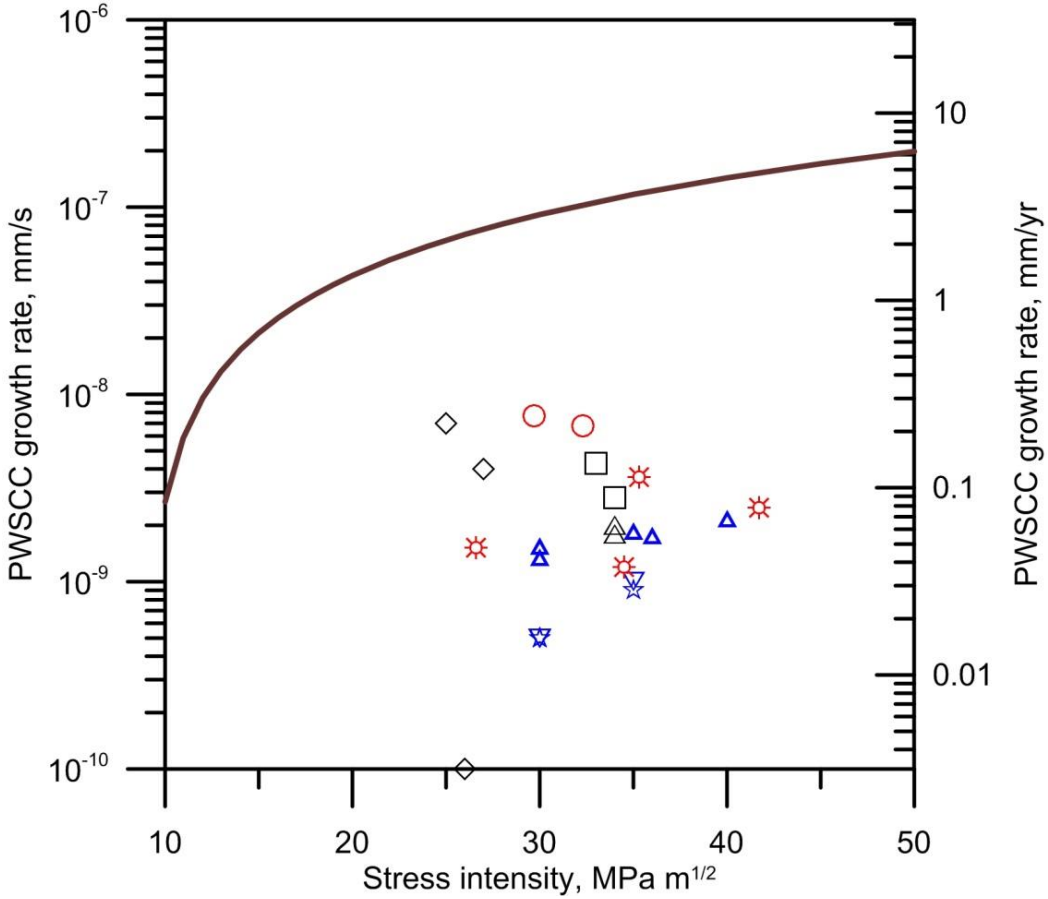
Alloy 690 HAZ



- Crack growth rates comparable to Alloy 690 without cold work
- Microstructure of alloy 690 HAZ is different from microstructure of the HAZ in alloy 600 or in 300 series SS

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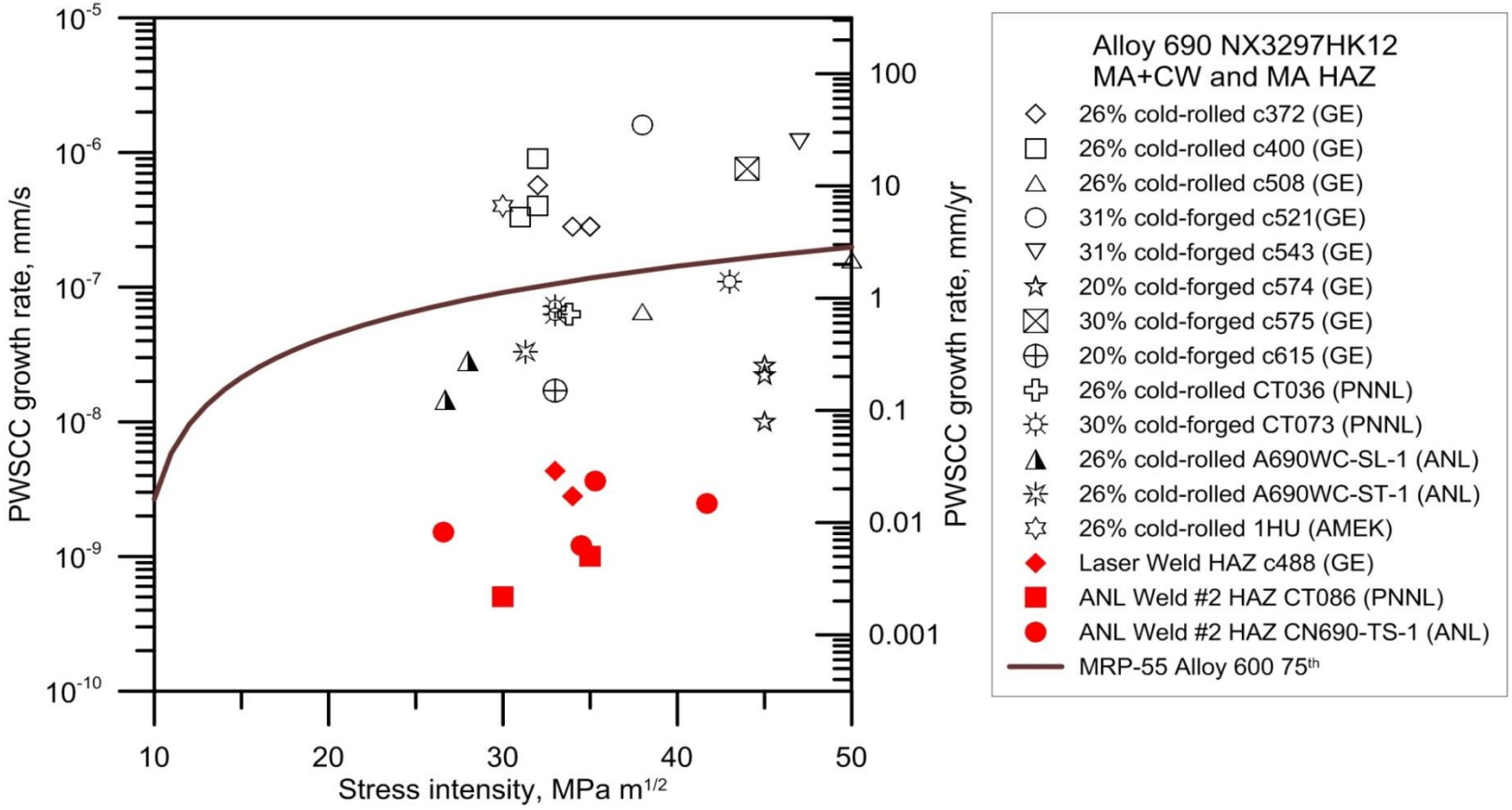
Alloy 690 HAZ and MA+CW



- Characterization results suggest that CW may not be an accurate simulation of a weld HAZ

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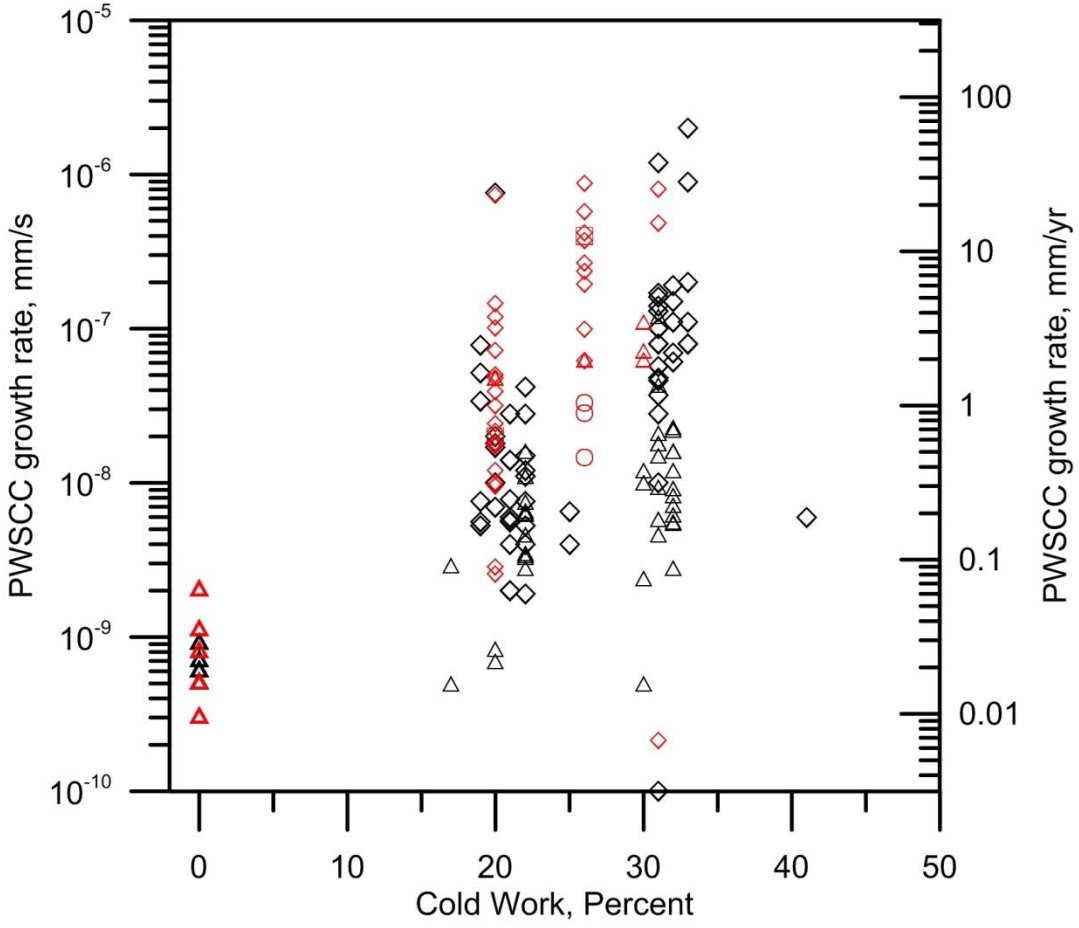
Alloy 690 Cold Worked



- Alloy 690 MA + CW may be more susceptible than Alloy 690 TT + CW
- Limited information on Alloy 690 with low levels of CW

- Need to determine significance of materials with high levels of CW

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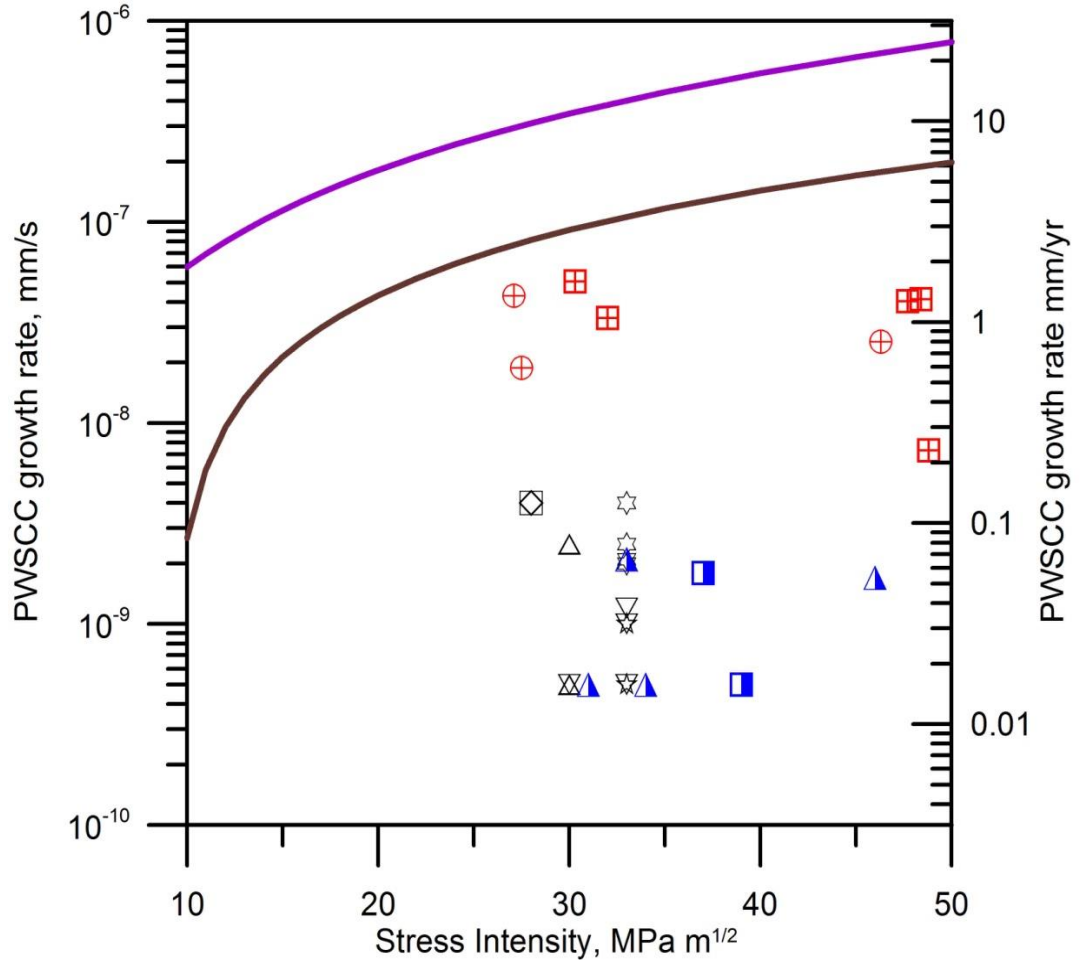
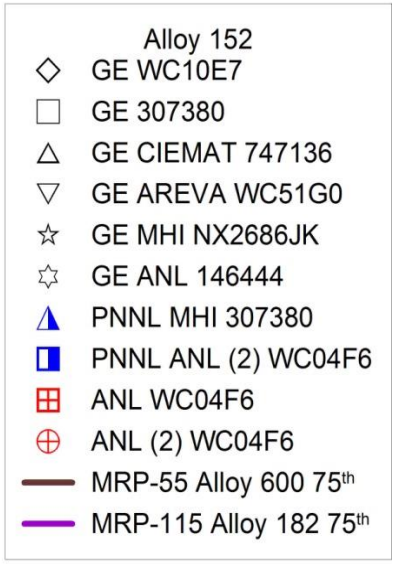
Alloy 152





- Most welds have low crack growth rates
- Initial weld produced by ANL showed medium and high crack growth rates
- New weld with same alloy 152 heat was tested

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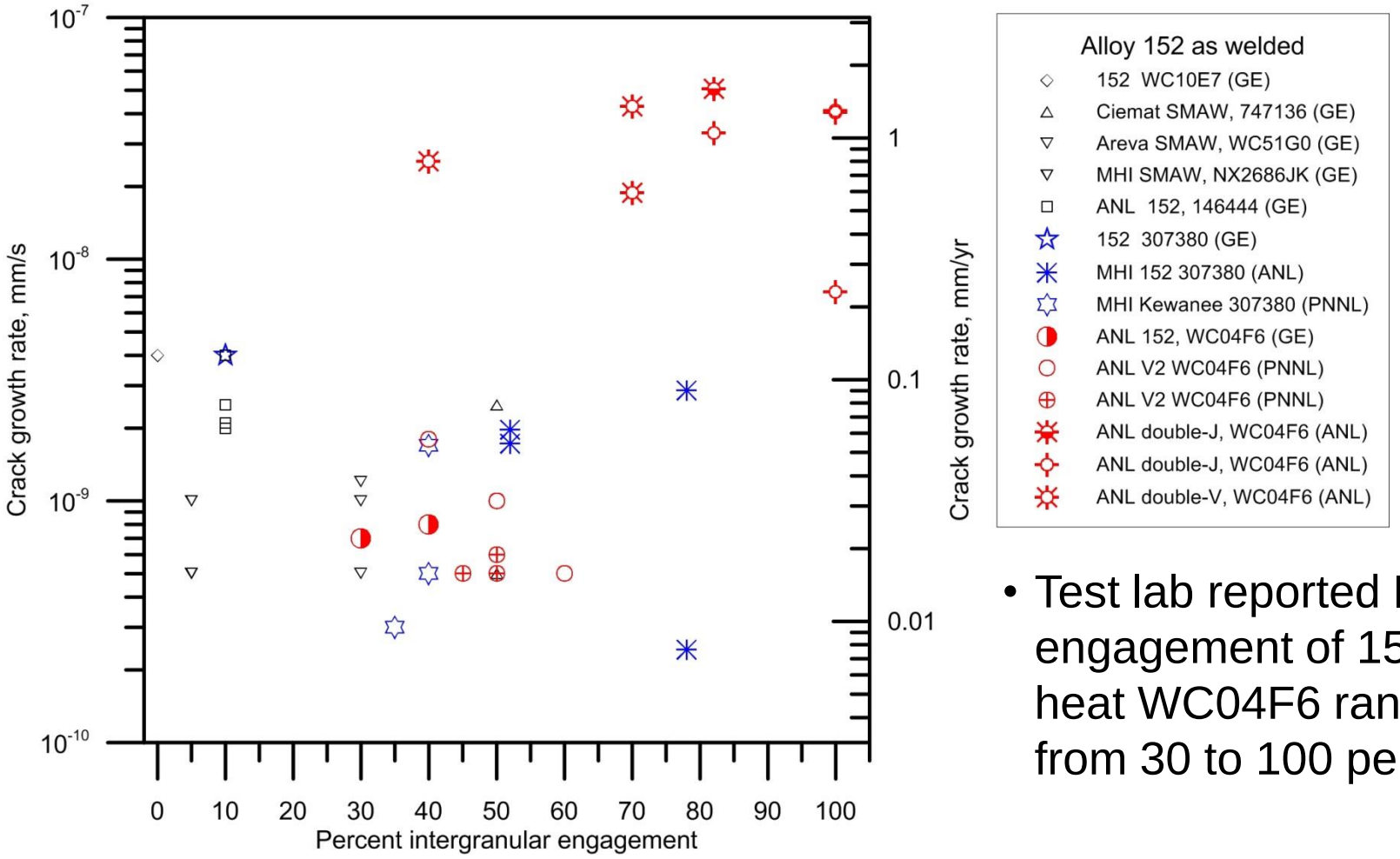
Alloy 152



- Test lab reported IG engagement of 152 heat WC04F6 ranges from 30 to 100 percent

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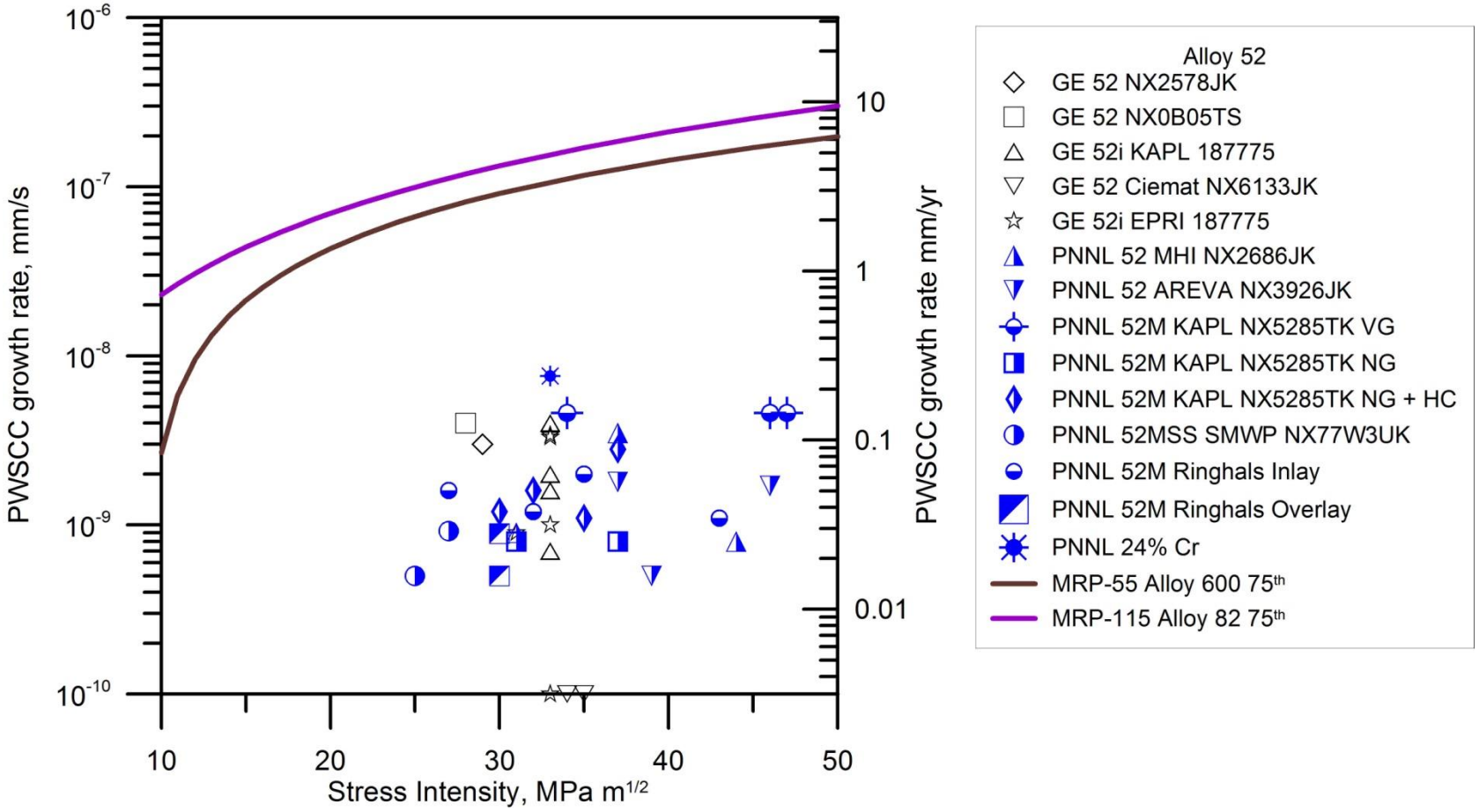
Alloy 52



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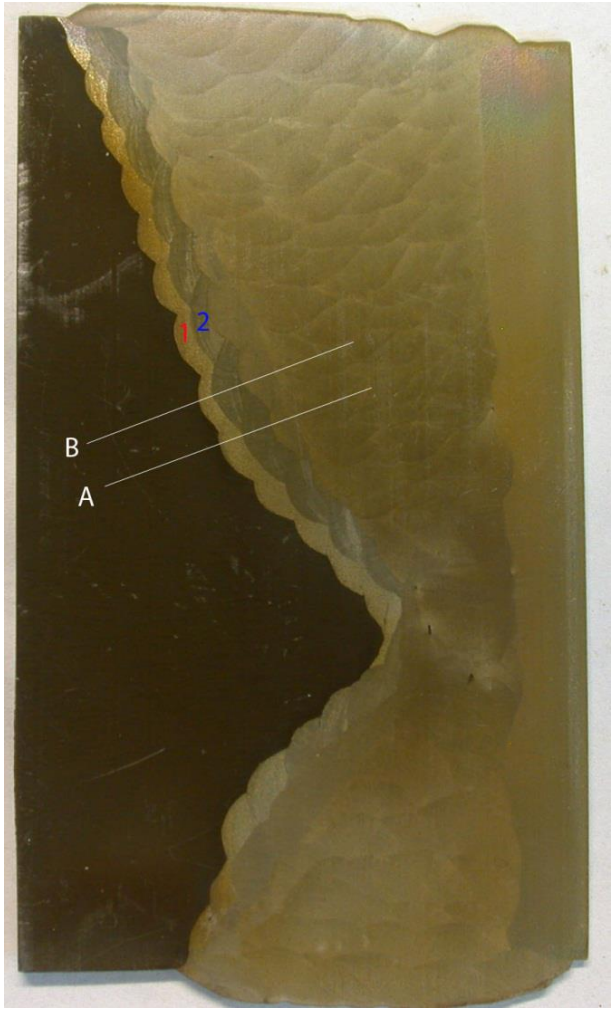
Weld Dilution Zones



- ANL produced Alloy 690/152/LAS dissimilar metal weld (DMW)
- LAS was buttered with Alloy 152 and post weld heat treated (PWHT)
- Weld procedure qualified and welding parameters were within Alloy 152 manufacturers recommendations
- Recent ANL tests show alloy 152 weld dilution zones have higher PWSCC susceptibility
- Characterization data for ANL test specimens is underway
- B. Alexandreanu presentation

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High priority gaps

Gap	Status
1. PWSCC susceptibility of HAZ	Limited tests show Alloy 690 HAZ does not have increased PWSCC susceptibility. Need to determine a path forward.
2. Effect of weld defects in 52(M)/152 on PWSCC susceptibility	Difficult to determine using crack growth rate tests. Perhaps better evaluated in PWSCC initiation tests.
3. Effect of weld composition & welding procedure (including dilution effects) on PWSCC and LTCP	Recent testing of 152-LAS dilution zones show increased PWSCC susceptibility. Limited data on effects of welding parameters.
4. Welding fabrication and repair effects on defect population, residual stresses and susceptibility	Need to obtain representative mockups to address this gap and characterization of weld repairs.

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Medium-high priority gaps

Gap	Status
5. Reduced resistance to PWSCC because of thermo-mechanical processing of Alloy 690 (e.g., 1-D rolling)	Extensive testing and material characterization has been conducted. Reduced resistance correlated with misorientation.
6. Resolution of contradictory CGR findings among labs for 52(M)/152	Heat WC04F6 appears to have higher susceptibility in some tests higher crack growth rates correspond to higher intergranular engagement. Other 152 heats show intergranular engagement up to 50% but low crack growth rates.
7. Relevance of thermo-processing modes (e.g., 1-D rolling) to plant installations	Information supplied by vendors

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Medium and Low-Medium priority gaps

Gap	Status
Importance of LTCP to operating plants for A690 and welds	LTCP not being addressed in this collaboration
CGR flaw disposition curves for A690/52/152	Ongoing, substantial discussion in 2012 meeting. Projected needs for ASME code and xLPR.
Detailed information on actual replacement components in the field	Information supplied by vendors
Crack initiation data on heterogeneously deformed A690 that has shown high CGR values	To be addressed in initiation testing

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Priorities for future work

1. Review of information gaps
   - Documentation for gap resolution
   - Reprioritization of remaining gaps
2. Dissimilar metal welds dilution zones
   - 152/stainless steel
   - 152/low alloy steel
   - 52M/stainless steel
   - 52/low alloy steel
3. Alloy 152/52 crack growth rates
   - Weld overlays and inlays with 152 and 52M
   - 152 weld material
   - Shielded Metal Arc Weld (SMAW) and Gas Tungsten Arc Weld (GTAW) parameters